



TITLE:

KUBO-TOYABE THEORY REVISITED BY MUONS AND STUDY OF DYNAMICS OF SPIN GLASSES

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超音波の減衰, その他の動的臨界現象の計算は未だである。生体膜は, 材料を適当に選ぶことによって, 生理的温度領域で, スピノーダル近傍が実現され, 凝臨界現象を演じている。細胞膜にあっても, これが生理現象の重要な一端を担っているかも知れない, というのが我々の夢である。

本研究は, 大学院生, 阿久津泰弘氏との共同研究である。

KUBO-TOYABE THEORY REVISITED BY MUONS

AND

STUDY OF DYNAMICS OF SPIN GLASSES

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In 1967 Kubo and Toyabe [1] formulated a stochastic theory of resonance line shape in a randomly oriented local field with Gaussian distribution at zero and low external field, but it has not attracted any attention among solid state physicists, simply because NMR is not possible at zero external field except for spin-ordered systems. The following unique features of zero-field spin relaxation have been recognized recently by muon spin physicists [2–5], where muon spin relaxation can be observed without assistance of external field.

i) The zero-field relaxation function of Kubo-Toyabe in the static limit

$$G_z(t) = \frac{1}{3} + \frac{2}{3} (1 - A^2 t^2) \exp(-\frac{1}{2} A^2 t^2)$$

damps but recovers to the hard-core value 1/3. This “1/3 tail” is extremely sensitive to slow modulation of local field (see Fig. 1).

ii) The second moment of nuclear dipolar field detected by the zero-field method shows enhancement by a factor 5 over the Van Vleck value, because the truncation due to external field is released (“5 effect” versus “10/3 effect”).

The zero-field relaxation method has been applied not only to nuclear dipolar systems, but also to atomic spin systems, such as spin glasses. This method is unique in detecting dynamical behavior

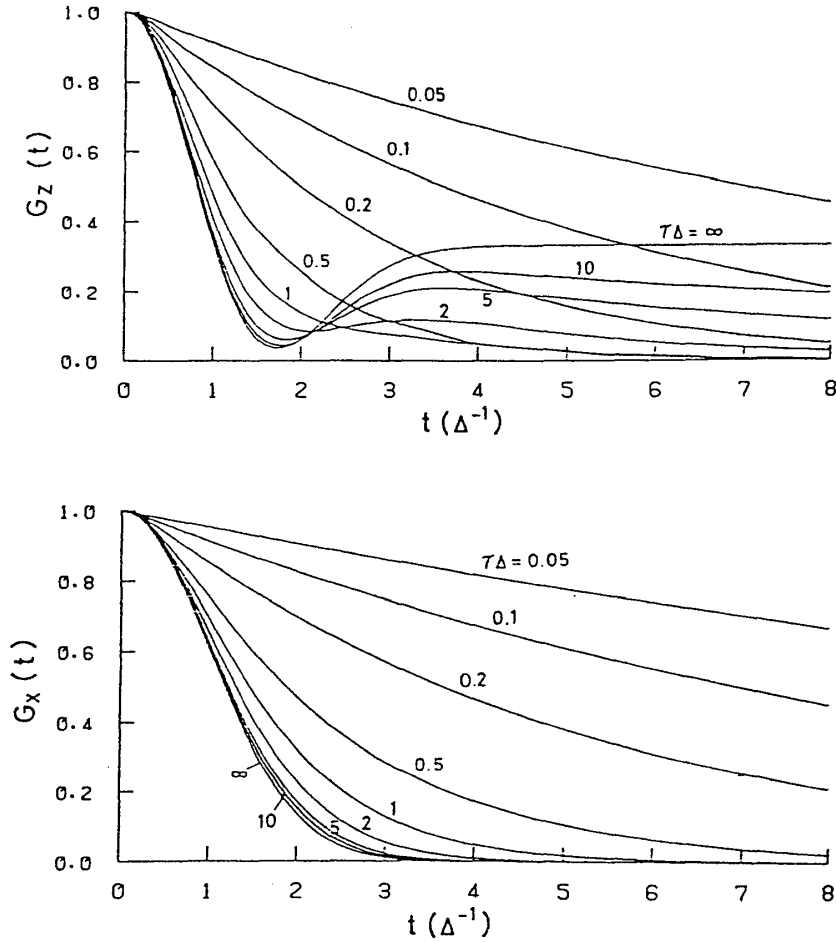


Fig. 1 (a) Zero-field relaxation function $G_z(t)$ for randomly oriented Gaussian local-field distribution (Kubo-Toyabe function), calculated by the strong-collision approximation. (b) High-field transverse relaxation function $G_x(t)$ under the same situation as (a). From Ref. [4, 5].

of spin glasses in a very wide range of correlation time; $10^{-4} \sim 10^{-10}$ sec [6–7]. The local field in a dilute spin system follows Lorentzian distribution. Recently, Kubo [8] has further extended the zero-field theory to the Lorentzian case, and Uemura [9] has formulated relaxation functions to be applied to spin glass system.

Actually, we have observed zero-field relaxation in AuFe and CuMn spin glasses and deduced correlation times (see Fig. 2 and 3). This experiment has revealed the following important features of spin dynamics.

- i) Rapid but continuous change of τ_c over the freezing temperature T_g .
- ii) Dynamical scaling: τ_c at T_g is roughly 10^{-8} sec.
- iii) Slow modulation in the freezing phase.

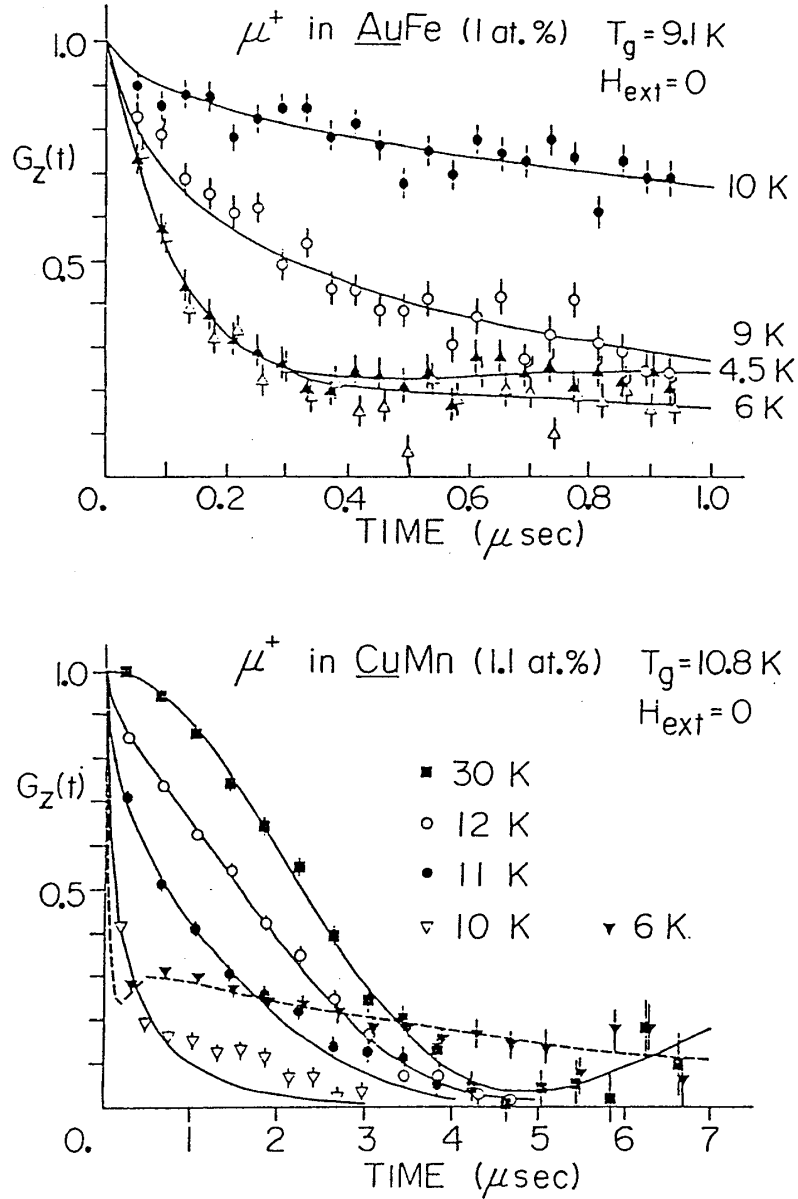


Fig. 2 (Upper): Zero-field relaxation functions of μ^+ observed in 1.0 at % AuFe. The solid curves correspond to $G_z^{\text{SG}}(t)$ with $a = 5.2 \mu\text{sec}^{-1}$. (Lower): Zero-field relaxation functions of μ^+ observed in 1.1 at % CuMn. The solid curves correspond to $G_z^{\text{SG}}(t) \times G_z^{\text{KT}}(t)$ with $a = 10.2 \mu\text{sec}^{-1}$ and $\Delta = 0.36 \mu\text{sec}^{-1}$ and the broken curve is $G_z^{\text{SG}}(t)$. From Ref. [6].

These features have been confirmed by a further experiment using a small longitudinal field [10]. This experiment has also shown that the correlation function may not be exponential with a single correlation time.

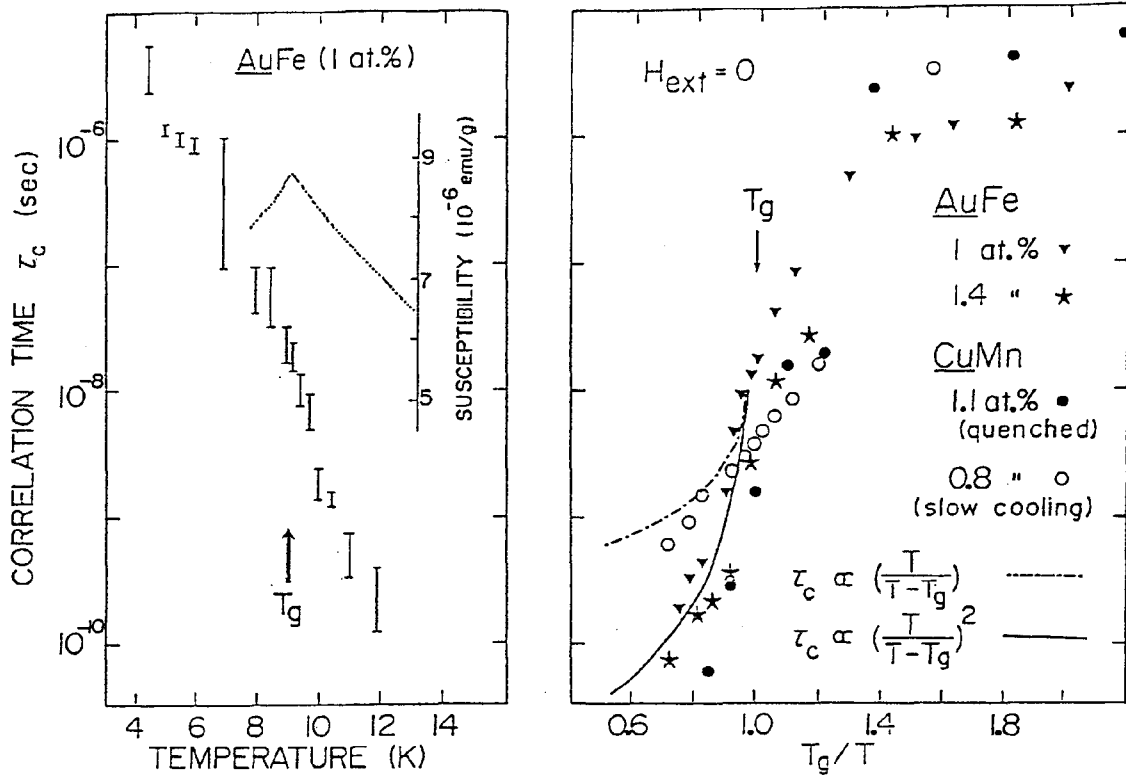


Fig. 3 (Left): Correlation times τ_c in AuFe (1.0 at. %, $T_g = 9.1$ K) deduced from the observed zero-field relaxation functions. (Right): τ_c versus, T_g/T for AuFe and CuMn spin glasses. From Ref. [6].

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